Hi-5 FF → Brunner Island

DEMONSTRATION OF STRATEGIES FOR IMPROVED BAGHOUSE PERFORMANCE

Randy L. Merritt
P. Vann Bush
SOUTHERN RESEARCH INSTITUTE
P.O. Box 55305
Birmingham, AL 35255-5305

Noel H. Wagner
Paul J. Knapp
PENNSYLVANIA POWER & LIGHT
Two North Ninth Street
Allentown, PA 18101

Ramsay L. Chang
ELECTRIC POWER RESEARCH INSTITUTE
3412 Hillview Avenue
Palo Alto, CA 94303

ABSTRACT

It is believed that the shortened bag life at the Brunner Island unit 1 baghouse is a direct result of acidic corrosion of the bag fabric. Furthermore, exposing the bags to condensed acid gases and water during startup and low load operation adds stress to the bags by accumulating heavy dustcakes.

During boiler startups, flue gas is routinely passed through the entire baghouse without the use of bypass dampers. Consequently, the baghouse passes through the water dew point temperature, and ash is added to the dustcake which is not removed during normal reverse-gas sonic-assisted cleaning. Eventually, the bags reach a weight which leads to accelerated bag failures.

A test program began in April 1990 to evaluate an alternate method of startup by passing flue gas through 8 designated "startup" compartments (during oil firings) to minimize the time that the remaining 16 compartments are exposed to flue gas at temperatures below the water dew point. In one of the startup compartments, limestone is injected at the compartment inlet during oil firings. Bag weight, relative drag, and fabric strength data were obtained which demonstrate the improvement in baghouse performance.

In addition, alternate fabrics and three types of sonic horns will be evaluated to determine the optimum benefit.

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INTRODUCTION

The Brunner Island station, operated by the Pennsylvania Power and Light Company (PP&L), is located in York Haven, Pennsylvania, about 100 miles west of Philadelphia. Brunner Island has three units fired with an eastern, bituminous, high-sulfur coal. When unit 1 began operation in 1960, it was equipped with an electrostatic precipitator (ESP). In 1967 a second ESP was added in parallel with the existing ESP. Unit 1 was retrofitted with a 24 compartment, reverse-gas-cleaned baghouse which came on line in October 1980. One ESP was retired, and flue gas was directed through the other ESP (that is de-energized) and into the baghouse. The ash handling system of the de-energized ESP is still used to remove dust from the hoppers. Units 2 and 3 are equipped with electrostatic precipitator collection devices. Design specifications for the unit 1 boiler and baghouse are detailed in Table 1.

Unit 1 output is controlled by a central dispatcher. It typically operates at full load conditions during daytime and is reduced to ~1/2 load for overnight hours. The unit operates at a higher capacity factor during extreme weather conditions and when other units in the system are down.

INITIAL BAGHOUSE OPERATION

Baghouse flange-to-flange pressure drop averaged ~4.0 in. H_2O for the first 6 months of operation. By April, 1981 baghouse pressure drop attained 5.2 in. H_2O, and the baghouse was in a continuous cleaning mode; each compartment was cleaned every 30 minutes. Adjustments were made to the cleaning cycle parameters, which resulted in minimal benefits. By the end of 1981, the baghouse pressure drop had attained 7.0-8.0 in. H_2O, and by mid-1982, the baghouse pressure drop exceeded 9.0 in. H_2O (at full boiler load, and with all compartments in service).

Excessive bag failures became a serious problem, as shown in the following table. Within 2 years of operation, all 24 compartments were rebagged to reduce baghouse pressure drop and replace failed bags (1).

Year	1980	1981	1982	1983	1984
Number of Failures	6	204	1064	1224	1005

Baghouse operation at Brunner Island was not typical of baghouse installations on coal-fired boilers. In 1982 the Electric Power Research Institute (EPRI) contracted with Southern Research Institute to diagnose the problem and evaluate potential solutions. Subsequent research efforts have been supported by a co-funding arrangement between PP&L and EPRI.

IDENTIFICATION OF BAGHOUSE PROBLEMS

The baghouse operation at Brunner Island was typified by the following conditions:

- High baghouse pressure drop
- High rate of bag failures
- Excessive dustcake weights

The high baghouse pressure drop was a result of high dustcake weights. Within two years of operation, bags containing over 150 pounds of dustcake had been weighed. To abate the rapid increase in dustcake weight, an evaluation of sonic horns was performed to determine the benefit of additional cleaning energy. Compartment-scale tests showed a 30% reduction in drag, and a reduction in average bag weight from 131 pounds (without sonic horns) to 84 pounds (with sonic horns). Eight Fuller sonic horns were installed in each compartment in January 1983. Subsequent analyses showed that the sonic horns were effective in reducing the rate at which bags gained weight.

One of the peculiarities of the Brunner Island baghouse operation was the ever-increasing bag weights. In a baghouse filtering ash from low-sulfur coal, bags will typically attain a bag weight of 40-60 pounds after 1 year, and will maintain this bag weight for a period of 5-6 years.

Bag weight has been a very discriminating gauge for measuring baghouse performance at Brunner Island. Historically, at Brunner Island bags continue to gain weight in a linear fashion as a function of time. Generally, bags will attain weights of over 100 pounds after a couple of years of operation. Typically, when bag weights exceed 100 pounds, the frequency of bag failures increases until the compartment is completely rebagged.

Excessive bag failures and an unacceptably short bag life are the most critical problems at the Brunner Island baghouse. For the period of October 1980 through August 1991, a total of 8139 bags had failed in the baghouse. The number of bag failures per year is presented in Figure 1. Total bag failures projected for 1991 are based on the current rate of failures.

The majority of compartments have been rebagged 5 times since the original installation of bags. The average time in service before a compartment was rebagged was 25.5 months. Figure 2 presents the average age of compartments when rebagged over the 11 years of baghouse operation. For a typical compartment installation, 69 bag failures occured over the 25.5 months average life of the compartment.

ANALYSIS OF BAGHOUSE PROBLEMS

Excessive bag failures and short bag life in the Brunner Island Unit 1 baghouse have been related to condensation of sulfuric acid in the baghouse compartments, promoted by baghouse operation at temperatures below the acid dew point. During these periods of operation below the acid dew point temperature, it is believed that the fabric is weakened by the formation of sulfuric acid. Subsequent or concurrent temperature excursions below the water dew point, during compartment maintenance or baghouse startups, result in ash being added to the dustcake in a form which is not subsequently removed during the cleaning cycle.

Evidence which points to this conclusion includes the following factors and observations.

- Visible metal corrosion and moist, sticky surfaces are typically seen inside compartments during inspections.
- Bag weights increase with time in service due to highly cohesive or sticky ash.
- Inleakage of ambient air into compartments (inlet elbows) has occurred, and subsequently resulted in massive bag failures.
- There is a strong correlation between increased bag failures following unit outages.
- Bag failure rates are basically independent of bag type.

Coals burned at Brunner Island produce concentrations of sulfuric acid vapor between 9 and 13 ppm in the flue gas entering the baghouse. This concentration has a dew point of ~280°F in the presence of flue gas with a 10% water content. This concentration of sulfuric acid is very high compared to other utility baghouse installations. Steam coils have been used to protect the air heater from acid corrosion by boosting the temperature of flue gas exiting the air heater to 300°F. Temperatures at the inlet to the baghouse are usually 5 to 20 degrees lower than the temperature measured at the exit of the air heater, depending on gas velocities.

PP&L is prohibited from bypassing the baghouse during boiler startups and shutdowns. This is an unusual feature of the Brunner Island baghouse since bypass procedures are common at other utilities. From the initiation of oil firing, the baghouse filters flue gas at temperatures below the water dew point (~115°F) for at least an hour. The baghouse is operated for extended periods below the acid dew point temperature (~280°F) during oil firings, and for a couple of hours after the initiation of coal feed.

The reverse-gas system does not circulate continuously, but deadheads when an individual compartment is not in reverse-gas cleaning. During a normal 30-second reverse-gas cleaning period, the temperature in the compartment (below the reverse-gas poppet) decreases ~40°F because of the cooler temperature of the reverse-gas, as shown in Figure 3. Currently, the reverse-gas period has a duration of 60 seconds, which would extend this acid dew point excursion.

The baghouse operates at temperatures near the acid dewpoint during low load conditions. Historically, at minimum load conditions, the baghouse temperature would sometimes drop to 270 to 280°F for several hours, although this was infrequent. During recent operations the steam coils have not been used. Consequently, baghouse inlet temperature was observed as low as 210°F during minimum boiler load conditions (4/30/91) and was generally 240 to 250°F at low load conditions. A return to the practice of maintaining 300°F at the exit of the air heater was implemented in September 1991.

The number of bag failures peaked in 1983 at Brunner Island with 1224 failures, and the number of failures decreased each year over the subsequent 5 years. However, the number of failures has increased for the past couple of years as shown in Figure 1. Repeated operation below the acid dew point is suspected to have contributed to the increased bag failures during this time period.

IMPLEMENTING POTENTIAL SOLUTIONS

Several approaches to improve baghouse performance at Brunner Island have been evaluated. The results and benefits of these evaluations are discussed.

Alternative Fabric Selections

Extensive tests of alternate bag fabrics were performed at Brunner Island between 1982 and 1985. The object of these tests was to identify fabrics which would operate with lower bag weights and a lower rate of bag failures. A wide variety of fabrics made of fiberglass filaments in different constructions, weights, and finishes were evaluated in compartment-scale tests. Additional novel fabrics were evaluated in a small, portable Fabric Filter Sampling System (FFSS).

Although subtle differences in performance existed among the various types, there were no significant differences in bag life for the various compartment-scale tests. Bag life was independent of fabric type, and was influenced by other factors. Two bags made of RYTON, a synthetic acid-resistant material, are currently being tested for fabric strength.

Ammonia Gas Conditioning

A technique for eliminating the condensation of sulfuric acid, and thereby protecting the bags from acid attack, is to inject ammonia gas into the flue gas upstream of the baghouse. Tests on a slipstream of flue gas using the FFSS were conducted in 1986, which demonstrated that ammonia gas could remove the sulfuric acid vapor from the flue gas. The reaction between ammonia gas and sulfuric acid vapor is

$$NH_3 + H_2(SO_4) \rightarrow NH_4HSO_4$$

$$NH_4HSO_4 + NH_3 \rightarrow (NH_4)_2SO_4$$

The intermediate product in the above reaction is ammonium bisulfate - a sticky, acidic liquid at temperatures above 293°F. The bisulfate will react with excess ammonia to form ammonium sulfate - a neutral solid at all temperatures that would be encountered in the Brunner Island baghouse. In the slipstream tests ammonia was injected at more than twice the concentration of sulfuric acid vapor in an effort to generate the ammonium sulfate product.

In addition to the removal of acid vapor from the flue gas, ammonia gas injection also caused a decrease in pressure drop across the filter. This result was attributed to an increase in the porosity of the cake formed on the fabric after the ash was exposed to ammonia gas or the products of the ammonia and acid vapor reactions.

Compartment-scale evaluation of ammonia gas conditioning was performed from April 1988 to December 1989. Two methods of ammonia gas conditioning were tested: continuous injection into a compartment, and injection into a compartment only when the temperature of the compartment dropped below the estimated acid dew point temperature. Performance of these two compartments were compared to an untreated compartment. During the evaluation, relative drag (resistance to flow) through the compartment, residual dustcake accumulation in the bags, corrosion of metals in the compartments, and the retention of fabric strength were documented.

Ammonia was injected at a rate to provide 35 ppm in the flue gas entering the two test compartments. The ammonia reacted with the 9 to 13 ppm of SO_3 in the flue gas, eliminating the SO_3 in the gases leaving the baghouse. The utilization of ammonia indicated a reaction with SO_3 in the stoichiometric ratio of 2 parts NH_3 to 1 part SO_3.

The NH_3 and SO_3 reaction caused 25 to 35% lower drag through the compartment exposed to continuous ammonia injection than through the control compartment that was not exposed to ammonia. Modification of the dustcake porosity by the reaction products of NH_3 and SO_3 is presumed to be the cause of the difference in drag.

Ammonia injection did not alter the rate at which residual dustcake accumulated on the bags. Increases in the weight of residual dustcake on the bags followed the historical trend of increases in dustcake weight versus time in service for the Brunner Island baghouse.

Fabric strength tests on bags removed after six months in service indicated that the bags in the compartment with continuous ammonia injection had retained more of their strength than the bags in the control compartment. However, subsequent tests after 11, 14, and 24 months of service indicated that bags in the compartment exposed to ammonia had less residual strength than the bags in the control compartment.

Deposits on the bags in the compartment exposed continuously to ammonia coated the fabric surface to the extent that the individual fibers could not be seen in photographs taken with an SEM. This feature of the deposits suggest that the product was collected in an amorphous state. That could mean the deposit was ammonium bisulfate when it initially collected on the fabric, and could have weakened the fiberglass fabric. If the deposit was made while the reaction product was NH_4HSO_4, further reaction with available NH_3 could occur and yield $(NH_4)_2SO_4$. Kinetics of the reaction between ammonia and SO_3 have not been determined for the test conditions, and so this reaction sequence is conjectural.

Injection of ammonia into the inlet of a baghouse compartment was not effective in preserving the strength of fiberglass bags, or altering the rate at which residual dustcake accumulated on the bags.

Alternative Baghouse Startup Strategies

During boiler startups, flue gas is routinely passed through the entire baghouse without the use of bypass dampers. Consequently, the baghouse is filtering ash at temperatures below the water dew point temperature (~115°F). Ash added to the dustcake during this period may not be removed during normal reverse-gas, sonic-assisted cleaning. (During the compartment-scale ammonia injection evaluation, a strong correlation between increases in bag weights and number of boiler startups was documented.) In addition, the occurrence of bag failures generally increase following periods of multiple boiler outages. Historically, Brunner Island unit 1 has experienced 10-12 (forced or planned) boiler outages per year.

During boiler startup with oil firing and initial coal firing, the boiler output flow rate is approximately 30% of normal full load conditions. The period of oil firing can range from 8 to 24 hours. A program began in April 1990 to evaluate an alternative method of passing flue gas through 8 (of 24) designated "startup" compartments during the boiler startup period. Following the beginning of coal firing, the remaining 16 compartments are placed in service, which minimizes the time that these compartments are exposed to flue gas at temperatures below the water and acid dew points. Eight compartments in the middle of the baghouse were designated as startup compartments for this evaluation.

During the evaluation of the use of startup compartments, relative drag (resistance to flow) through the compartment, residual dustcake accumulation in the bags, and the retention of fabric strength were documented.

Temperature surveys at multiple locations in the baghouse compartments were performed during several boiler startups. Figure 4 shows the air heater outlet temperature and the compartment temperature in a startup and a non-startup compartment during this period. Temperature surveys during the normal startup configuration using all compartments for oil firing, showed the compartment warmed more slowly because of the lower flow rate than when using 8 startup compartments.

A preliminary indication of the benefits of using startup compartments is presented in Figure 5, which shows bag weights versus time in operation for the startup and non-startup compartments. The bag weights for the non-startup compartments are generally lower than comparable startup compartments. The data for the startup compartments include those compartments which have operated as startup compartments and older compartments installed prior to this test program, which experienced startup during the normal startup procedure.

The use of startup compartments during boiler startups are being evaluated, although boiler shutdowns can also be potentially damaging. The boiler is purged with ambient (moist) air for a couple of hours after shutdown. Boiler purging requires 100% air flow, so all baghouse compartments are required to be in service, since the baghouse is not bypassed.

Limestone Precoat During Startup

One of the operating schemes to be evaluated in this program is the effect of limestone precoat on a single compartment during boiler startup. Compartment-scale testing was conducted at the EPRI HSFP in Sneads, Florida with various conditioning agents. After 8 months of operation, the bags in a compartment receiving continuous limestone injection retained 100% of their original fabric strength. Bags which had not received any conditioning lost ~20% of their original fabric strength.

Compartment 10B in the Brunner Island Unit 1 baghouse was rebagged in January 1991 and has received limestone injection during 4 of the 5 boiler startup periods that have occurred since the compartment was rebagged. 200 to 400 pounds of limestone is injected into the compartment inlet elbow during oil firing. The average bag weight in compartment 10B in August 1991 was less than in other startup compartments with similar time in operation, although long-term bag weight data, future fabric strength analysis and additional boiler startup periods are required to clearly gauge the effect of limestone precoating of startup compartments.

Evaluations of Original and Alternative Sonic Horns

From review of the bag weight data spanning 1985-1991, an additional pattern existed which was related to years of baghouse operation. Bag weight data available from three distinct time periods were grouped accordingly. Figure 6 presents the individual bag weight data and the curves fit to the three data periods. The data suggest that the rate of increase in bag weight increased over the time period 1985-1991. A gradual deterioration of the sound pressure levels from the sonic horns may have contributed to this change.

New horn types are being evaluated in three compartments. Each compartment is installed with 4 horns, as suggested by the horn manufacturers. The performance of these new horn types will be compared to the original Fuller horns (8 horns per compartment) installed in compartment 9A, which were recently refurbished with new diaphragms. Envirocare horns were installed in compartment 6A in August 1991. Installation of BHA Group horns in compartment 7A and Corona horns in compartment 9B are scheduled in the near future.

Sound pressure measurements were made before and after the new sonic horn installations were completed. Sound pressure measurements had been made during the original horn installations in 1983, although only 3 vertical positions were measured. During the present evaluation, measurements were made at 34 vertical positions to provide more definition of the sound pressure distribution. A data summary is presented in the following table.

Table 2. SONIC PRESSURE MEASUREMENTS - AUGUST 1991

Comp	Old Configuration		New Configuration		
	# of horns	Sonic Pressure, Pa	Manufacturer	# of Horns	Sonic Pressure, Pa
6A	8	60.1	Envirocare	4	87.8
7A	12	63.4	BHA Group	4	
9B	8	74.7	Corona	4	
9A	8	73.9	Fuller, new diaphragms	8	83.7

Installation of 4 new horns in compartment 6A did not provide an even distribution of sonic pressure throughout the compartment. Prior to installing the new horns, bags averaged 124 pounds, and there was no correlation to location in the compartment. With the new horns in compartment 6A, the bags in the vicinity of the horn lost 20-30 pounds; in the middle of the compartment, furthest from the horn placement, the bags gained 20-30 pounds.

Bag weight and sound pressure data are incomplete for the new horn installation, and must be followed for several months to determine the preferred horn configuration.

SUMMARY

The Brunner Island Unit 1 baghouse is very sensitive to operational changes. A record number of bag failures has been very costly for the utility. Many of the baghouse problems are suspected to be caused by operating excursions below the acid dew point. Being prohibited to use bypass dampers on boiler startup requires innovative startup procedures to protect the baghouse.

Several potential solutions have not been beneficial, including alternative fiberglass fabrics, and the use of ammonia gas conditioning to reduce acid attack of the bags. Current evaluations of alternative baghouse startup strategies, limestone precoat during startup, and alternative sonic horns are generally encouraging, although long-term operation is required to clearly gauge the benefits of these strategies.

REFERENCES

1. Noel H. Wagner. "Present Status of Bag Filters at Pennsylvania Power and Light Company." In Proceedings: The Second Conference on Fabric Filter Technology for Coal-Fired Power Plants, EPRI, Denver, CO, March 1983.

Table 1. UNIT 1 BOILER SPECIFICATIONS

Unit 1 Rating	354 MW
Manufacturer	Combustion Engineering, Inc.
Date on line	1960
Initial firing (startup)	No. 2 fuel oil
Boiler type	Tangentially fired
Steam flow	2,200,000 lbs/hr
Coal type	Eastern bituminous
Coal heating value	12,000 Btu/lb
Coal sulfur content	1.8 to 2.0%
Coal ash	15%

BAGHOUSE DESIGN SPECIFICATIONS

Manufacturer	Carborundum
Date on line	October 19, 1980
Cleaning mode	Reverse-gas
Air flow	1,200,000 acfm
Baghouse pressure drop	6.0-7.0 in. H_2O
Normal baghouse temperature	330°F 250°F @ TIMES
Inlet loading	< 7.0 gr/acf
Outlet loading	0.10 gr/acf
Number of compartments	24 (2 rows of 12)
Filter bags per compartment	264
Filter bag length	35 feet 4 inches
Filter bag diameter	11.5 inches
Filter Material	Teflon-coated fiberglass
Top bag suspension method	Chain and compression spring
Bottom retainment method	Compression band sewn in bag cuff
Air-to-cloth ratio (gross) 1.88	~~1.83~~ $acfm/ft^2$
Air-to-cloth ratio (net) -4	1.98 $acfm/ft^2$ 2.33 w/2 cleaning 2 maintenance

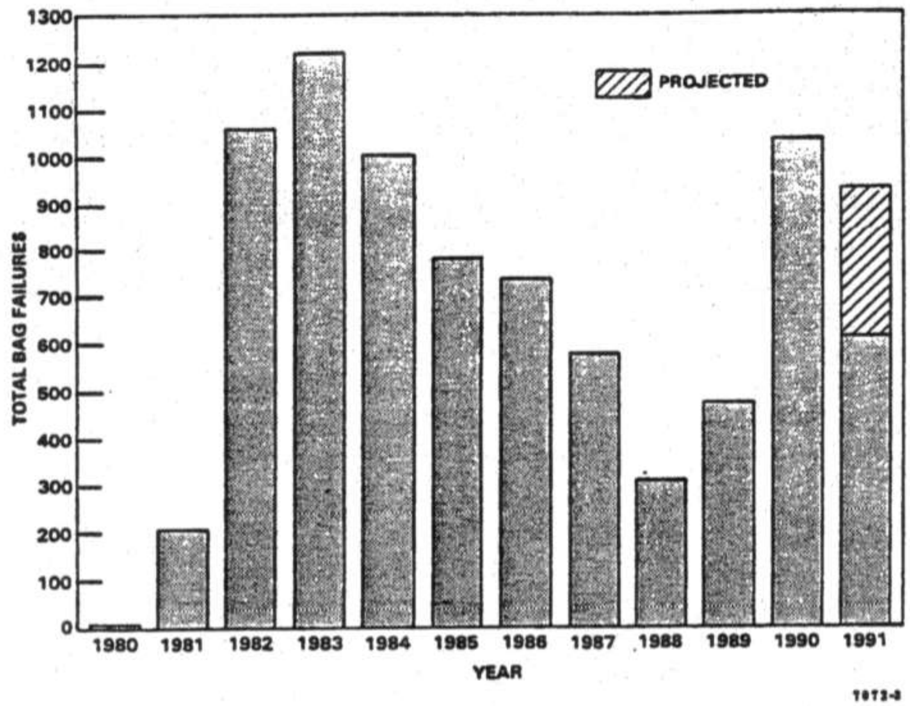

Figure 1. Total bag failures per year.

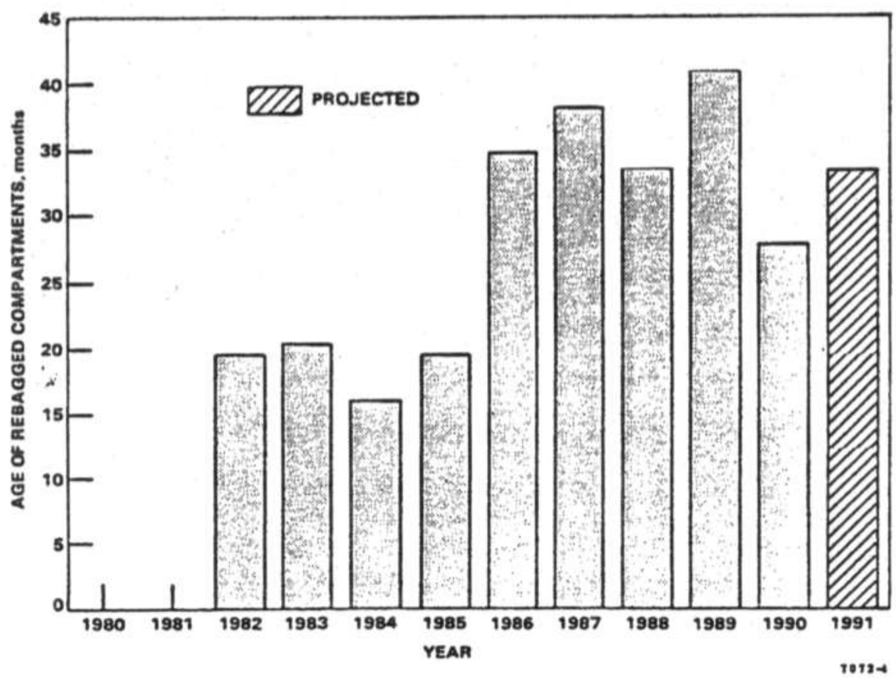

Figure 2. Age of compartments when rebagged.

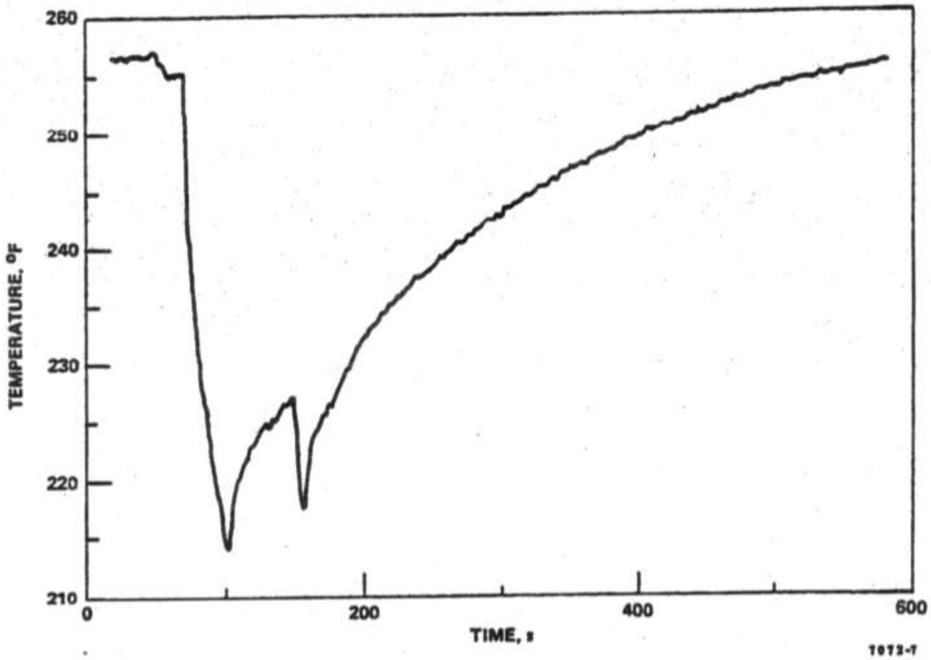

Figure 3. Compartment temperature during reverse-gas period.

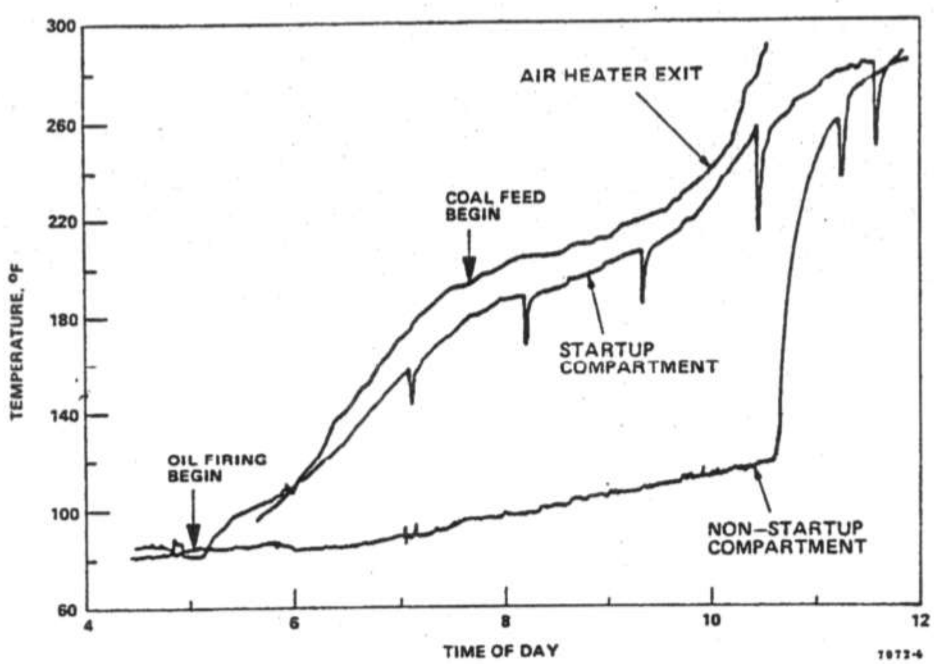

Figure 4. Startup compartment, non-startup compartment, and air heater temperature during startup.

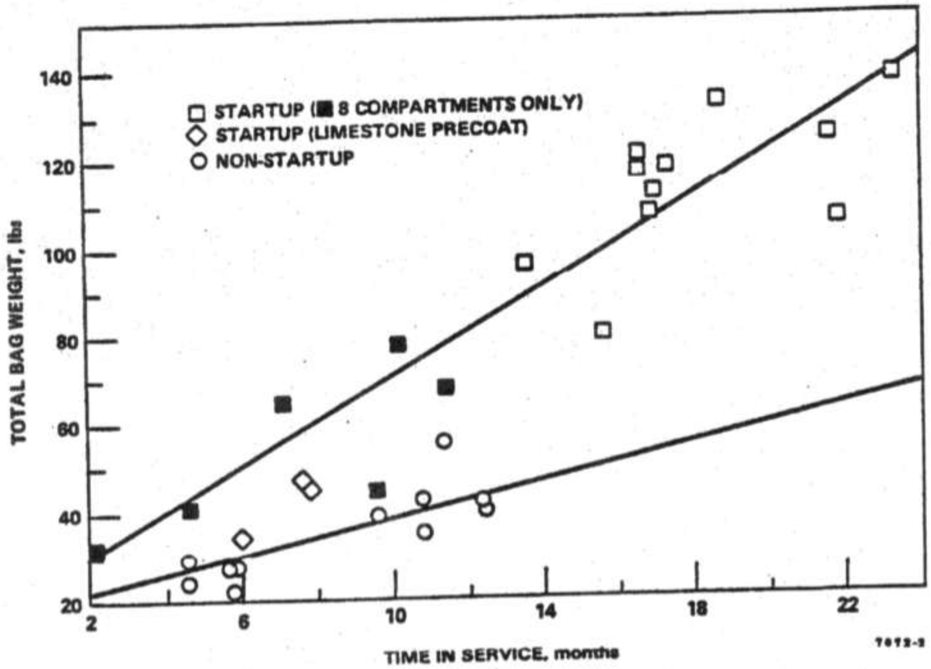

Figure 5. Bag weight versus time in service.

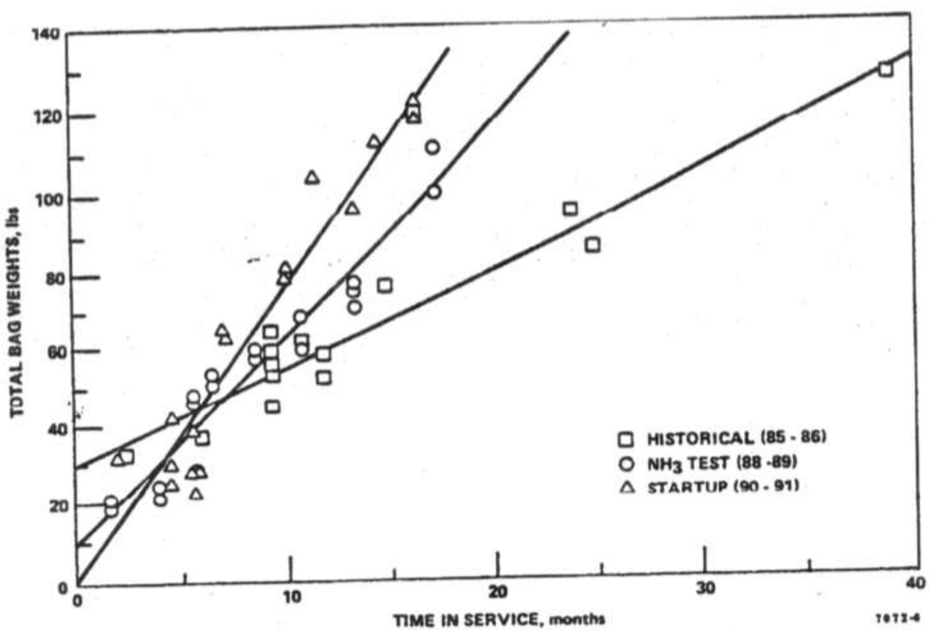

Figure 6. Historical bag weight versus time in service.